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Novel Research Methods Supporting Advanced Waste Treatment Technologies within a Circular Economy

Edward Randviir describes a practical application of the Living Lab approach to an investigation into the failure of a waste treatment tank.

One of the principles of the circular economy is to ensure that maximum use is obtained from the materials we consume and that the use of virgin materials is minimised; it is a philosophy that underpins European Union policy instruments[1,2,3]. As a result of these policies, a large burden has been placed upon the waste management sector in the UK, as they have been identified as one of the major links to the future of a circular economy. One response to such instruments at a local authority level, is to implement advanced waste treatment technologies such as anaerobic digestion, in-vessel composting , or 'Energy from Waste' facilities so as to extract maximum value from waste, minimise waste to landfill, reduce climate change impacts, recycle more materials, and create new jobs. This has required the upgrading of existing infrastructure, and the design and construction of new infrastructure. An unforeseen consequence of these novel operational systems has been the need to ensure the ongoing health and longevity of the technologies.

Technologies and infrastructure that treat large amounts of waste, such as anaerobic digestion plants, can be subject to physically and chemically aggressive conditions that are difficult to control. The consequences of this are failures, such as the erosion of concrete, corrosion of steel, the degradation of protectors and coatings, the pitting of stainless steel and blockages to pipework. Downtime of treatment processes not only increases running and maintenance costs, but also limits

the ability to maximise the reuse of waste and increases the diversion of waste to landfill. This is detrimental to the fundamental principles of the circular economy. It is therefore imperative for industry to invest in resources to tackle such issues and to plan for downtime arising from operational failure.

The Waste 2 Resource Innovation Network (W2RIN) at Manchester Metropolitan University was established to address exactly such challenges. The core team, within the Faculty of Science and Engineering, comprises staff with a wide variety of expertise including (but not limited to) chemical and biological technology, policy interpretation and legal compliance, waste collection, contract procurement and management, transport logistic planning, waste treatment feedstocks and material markets, engagement techniques and behavioural change. We believe a full holistic approach is required to address the range of issues that occur within advanced waste treatment. The combination of this expertise allows for a user-centric approach towards addressing technical (and other) challenges faced by the waste management industry through liaison with plant operators, and middle and senior management. This approach effectively uses waste treatment processes as a 'Living Lab' that allows academic research methods to be implemented in innovative ways. We have contributed our expertise to understanding several problems encountered within the waste industry, such as anaerobic digestion and in-vessel composting corrosion, the identification of odour control system failures, the recycling of new wastes arising from advanced processing and the optimisation of sludge management processes.

ASSESSMENT & DIAGNOSIS OF HYDROLYSIS TANK FAILURE

An example of this type of this approach is provided by an investigation into the failure of a hydrolysis tank at a municipal solid waste treatment plant. The tank investigated has a holding capacity of 4,000,000 litres of organic sludge derived from municipal solid waste, and is responsible for treating approximately 250,000 litres of sludge per day. Waste sludge is chemically broken down into digestible material for the purpose of methane production, which is then used as a gaseous fuel in a combined heat and power generator, producing electricity to meet the needs of the entire waste treatment site. The failure of the hydrolysis tank meant that the site was unable to process the organic waste, so less waste was recovered and more waste had to be transported for incineration or diverted to landfill; ultimately less energy was then generated by the combined heat and power engine.

A failure in the integrity of the hydrolysis tank was discovered when an operative found an orange residue dripping from its outer walls. Upon closer inspection, the operative accidentally pierced the 8 mm thick tank wall with his finger which, in turn, revealed that the

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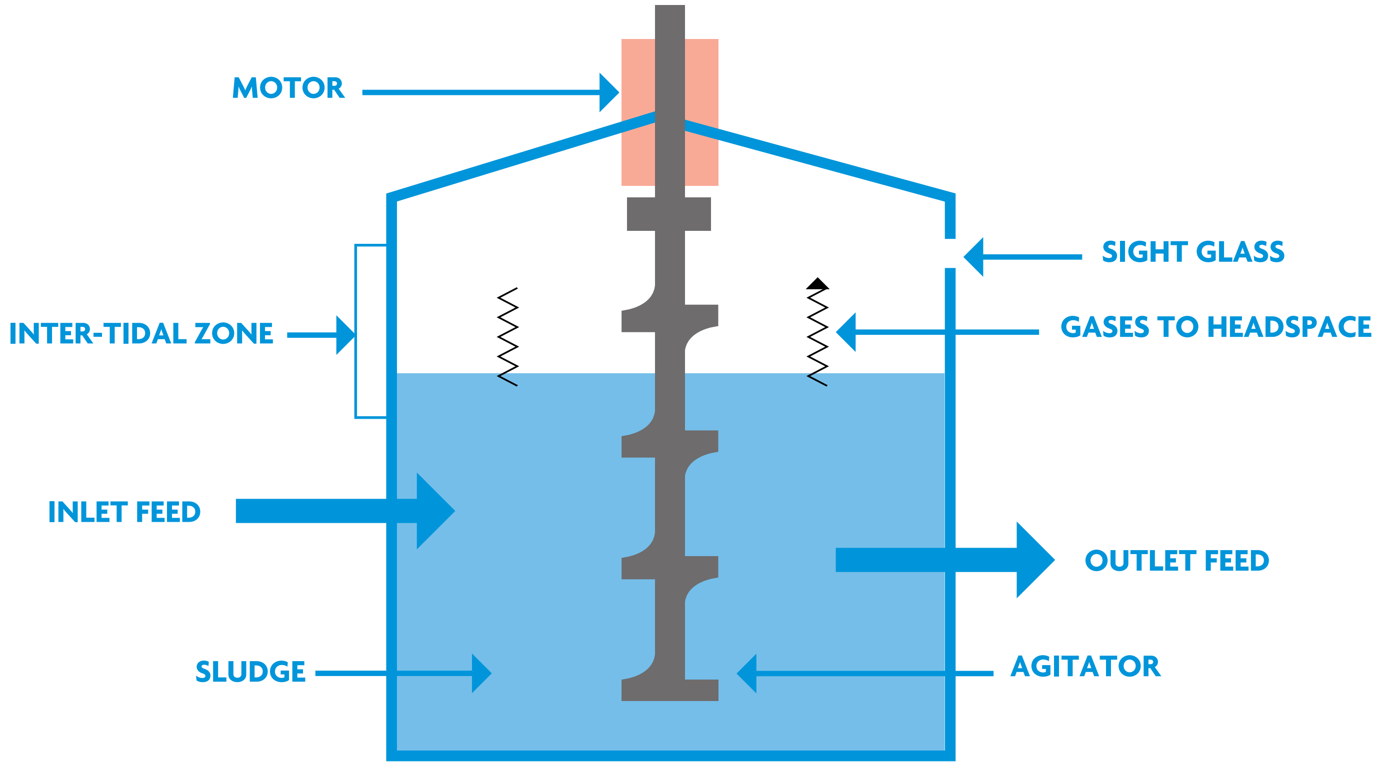

▲ **Figure 1. Not-to-scale diagram of the hydrolysis tank.**

tank was suffering from irreparable corrosion from the inside, despite the tank being lined with a protective epoxy coating. The tank had to be immediately drained and supported with scaffolding to stabilise the structure, thereby incurring significant operational and financial cost. An inquest then convened to determine the causative mechanisms of the corrosion. It was at this stage that W2RIN were brought in to provide expert advice, based upon a scientific evaluation of the probable causes of the corrosion, to enable the tank and the process to be redesigned and rebuilt.

METHODS EMPLOYED

The approach adopted by W2RIN was multi-faceted in nature. Firstly, a visual assessment was completed to determine the nature of the tank corrosion and to identify any patterns in the corrosion profile. It was found that the corrosion was almost exclusive to the headspace region of the tank, known as the 'intertidal zone' (see Figure 1), which is where the sludge surface line inside the tank rises and falls. Within this narrow region there were several areas that had completely corroded, implying that something was occurring within this region of the tank that was either occurring more rapidly than elsewhere in the tank or was not occurring at all in other parts.

Secondly, sample scrapings were taken from the tank walls in the affected region for forensic scrutiny in the laboratory using elemental mapping techniques and DNA profiling. Although sulphur does naturally occur in waste materials and is responsible for its many odours, concentrations do not normally exceed 2 per cent by weight. In the headspace, the sulphur content was in excess of 30 per cent by weight. A bespoke DNA profiling method designed for this study identified a sulphur bacteria species (*Acidithiobacillus thiooxidans*) that, in using the sludge as a feedstock, was producing this sulphurous environment. Using these techniques, a picture of the chemical and biological environment in the headspace was formed and found to be significantly different to non-corroded regions of the tank.

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Finally, to ascertain how the bacterium was penetrating the epoxy lining (and thus leading to steel corrosion), acidity tests, degradation experiments, and bespoke computer modelling software were used. Acidity tests in the intertidal zone found a very low pH of 1.5, indicating an environment over 10,000 times more acidic than expected in the tank (normally a pH range of 5.5–7.0 is expected). *Acidithiobacillus thiooxidans*, the dominant species found in the intertidal zone, is known to produce a highly acidic environment by releasing sulphuric acid as a metabolic by-product. Steel samples coated with the epoxy lining and then treated with sulphuric acid showed enhanced coating degradation in the presence of the acid. This confirmed information implied by the coating technical datasheet that sulphuric acid would penetrate the epoxy lining within 12 months if left unchecked.

DISSEMINATION

All experimental data was collated and presented to the client. Following subsequent discussions with various stakeholders, including the manufacturer of the tank, it was concluded by the tank managers that the hydrolysis process itself was responsible for the formation of the bacterial communities, and the current epoxy lining was not fit for purpose. Our client stated: “We have been working closely with W2RIN for approximately 3 years and they have been a huge benefit to us on many process projects. We had been experiencing corrosion issues on the hydrolysis tanks that are a part of the anaerobic digestion facilities located in Greater Manchester. We contacted W2RIN and asked for their help in understanding the chemical attack that was occurring in the tanks. Dr Edward Randviir visited both anaerobic digestion facilities and commenced a round of sampling from several areas of the tank. Once the samples had been analysed, they produced a report and presented their findings to all parties involved. The investigation work enabled us to understand the root cause of the problem and make necessary recommendations to the contracting company. We look forward to continuing our close working relationship with W2RIN for many more years to come”.

W2RIN, therefore, used a variety of scientific research methods to successfully provide valuable information for the redesign of the process and recommended a rebuild of the existing hydrolysis tank. This project provides an example of where modern bespoke laboratory based research methods can support the principles of the waste hierarchy and help drive the design of new technologies and infrastructure required to support the journey towards a circular economy. The combination of research methods and scientific thinking, typically unavailable to most waste plant managers, allowed for a quicker resolution to the issue so time could be spent more productively on redesigning the process. It also resolved the problem at source, rather than simply delivering a short-term repair. This Living Labs approach has proven to be successful across several different projects within the waste management industry and could be applied to several other industries too.

The move towards a circular economy will require the development of new, sometimes untried and tested technologies and infrastructure. This brings with it new commercial, legal and operational risks. The economic burden of landfill cost coupled with the EU policy tools, has made it imperative that the ongoing health of advanced treatment plants are regularly monitored. The work of the W2RIN at Manchester Metropolitan University has demonstrated that, with the appropriate expertise and instrumentation, academia plays a niche role in assessing operational design and providing solutions to prevent costly down time of advanced waste treatment technologies. **ES**

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REFERENCES

1. European Commission (2014) Towards a zero waste economy: A zero waste programme for Europe. ‹http://eur-lex.europa.eu/resource.html?uri=cellar:aa88c66d-4553-11e4-a0cb-01aa75ed71a1.0022.03/DOC_1&format=PDF› accessed October 2017
2. The European Parliament and the Council of the European Union (2000) Directive 2000/76/EC of the European Parliament and of the Council of 4th December 2000 on the incineration of waste. Official Journal of the European Union, L322/91 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000L0076&from=EN accessed October 2017)
3. The European Parliament and the Council of the European Union (2008) Directive 2008/98/EC of the European Parliament and of the Council of 19th November 2008 on waste and repealing certain Directives. Official Journal of the European Union, L312/3 ‹ http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN› accessed October 2017